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Physico-Chemical and Pasting Characteristics of Flour and Starch from Achi *Brachystegia eurycoma* Seed

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Abstract: Starch from 'achi' *Brachystegia eurycoma* seeds was isolated by wet milling process and physico-chemical properties and pasting behaviour of achi flour and starch were analyzed. The *Brachystegia eurycoma* flour contained 10.25% of moisture, 12.77% of crude protein, 10.52% of crude fat, 1.48% of total ash, 2.2% of crude fibre and 58.77% of starch content. The *Brachystegia eurycoma* starch had low content of 0.61% protein, 0.25% fat, 0.69% crude fibre, 0.79% ash, 84.28% starch, respectively. The amylose content of *Brachystegia eurycoma* starch was 20.88%. The swelling power, solubility, water and oil absorption capacities and the amylose content of the starch were found to be higher than *Brachystegia eurycoma* flour, but reversed is the case for starch amylopectin. There were significant differences ($p<0.05$) in the pasting properties of the samples. The factors which influence the pasting characteristics resulting to decrease Peak Viscosity (PV), Trough (TV), Setback (SB) and Final Viscosity (FV) of *Brachystegia eurycoma* flour compared to the starch are attributed to the interaction of starch with the protein, fat, etc. These factors play an important role in governing the pasting properties of starch. The swelling power of the flour (9.64%) and starch isolate (10.05%) place *Brachystegia eurycoma* seed in the category of restricted-swelling starch.

Key words: *Brachystegia eurycoma*, starch, flour, chemical composition, pasting, amylose

INTRODUCTION

Grain legumes are major sources of dietary proteins in the developing countries, as animal proteins are expensive. In addition to their protein contributions, legumes are also rich in other nutrients such as starch, dietary fiber, protective phytochemicals, oil, vitamins and mineral elements (Saikia *et al*., 1999). Legumes contain about 60% carbohydrate including starch, reducing and non-reducing sugars, oligosaccharides of the raffinose family, etc. (Shimelis *et al*., 2006). Research efforts are being directed to identify and evaluate unexploited sources as potential sources of dietary protein for feeding the world of tomorrow.

Brachystegia eurycoma is one the lesser known legumes, which have not been fully utilized to alleviate the problem of protein-energy malnutrition common in developing countries of the world such as Nigeria. In some states of Nigeria, *Brachystegia eurycoma* is called 'achi' in Igbo, akalado or eku in Yoruba; akpakpa or apaupan by the Ijaws and 'dewen' in Bini. *Brachystegia eurycoma* 'achi' which is popular in the Eastern part of Nigeria, is a woody plant mostly found in the rain forest zone and the seed has 10.47% protein and total carbohydrate content of 71.94 (Enwere, 1998), is seasonal but its use in soup making is not seasonal (Keay *et al*., 1974).

In order to increase the *Brachystegia eurcycoma* production and utilization, one of the approaches will be to exploit its major components starch through value-added product design and development strategy.

The utilization of *Brachystegia eurycoma* as a potential raw material for the production of starch is one of the aims of this study. Starch is convertible to many useful materials by chemical and biochemical techniques, as well as by fermentation (Eliasson, 1996). It plays an important role in food industries because it affects the physical properties of many foods and it mainly uses as thickener, water binding, emulsion stabilizer and gelling agent. Starches from various plant sources have their own unique properties that enable them to tolerate a wide range of processing techniques as well as various distribution, storage and final preparation conditions (Daniel and Waver, 2000; David and William, 1999; Buleon *et al*., 1998). Starch characteristics such as swelling power and solubility pattern, pasting behaviour and physico-chemical properties are important for improved quality of food products and could be utilized

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for the development of composite blends from *Brachystegia eurycoma* at small scale industry level as value-added products.

The objective of this study is to determine the physico-chemical properties and pasting characteristics of flour and unmodified starch from *Brachystegia eurycoma* seeds.

MATERIALS AND METHODS

Source and preparation of sample: Samples of *Brachystegia eurycoma* seeds were obtained from 'achi' Ejmu River in Abakaliki, Ebonyi State, Nigeria. The seeds were screened to eliminate the bad ones. One kilogram of cleaned *Brachystegia eurycoma* seeds were conditioned to 25% moisture content by the addition of 4 L of distilled water and held for 3 h at 28±2°C with occasional stirring. The conditioned sample was sun dried to final moisture of approximately 10%. The dry seeds were dehulled for 2 min using disc attrition mill (No. 1A Premier). The dehulled seeds were milled in an attrition mill and sieved with American standard sieve number 40, with aperture of 435 μm, packaged, labeled and stored at room temperature (28±2°C) in water and airtight polyethylene bag until used.

Starch isolation: *Brachystegia eurycoma* flour was steeped in distilled water (1:7) for 12 h at pH 12 at 28±2°C, washed and ground for 10 min in a crown star mixer electric blender (model: CS-BL100B) at high speed. The slurry obtained was re-suspended in 1 L of distilled water. The suspension obtained was filtered through a 60-mesh screen and the slurry obtained sieved through another mesh (200-mesh screen). The filtrate was allowed to sediment for 12 h and the supernatant decanted. The starch cake was then dried in a conventional oven at 50°C for 12 h, then ground and sieved through 400-mesh screen. It was stored in polythene bag until use. Starch yield was determined from the formula:

$$\text{Starch yield (\%)} = \frac{\text{Weight of 'achi' seed ground} - \text{weight of starch}}{\text{Weight of 'achi' seed ground}} \times 100$$

Color and pH value measurement: *Brachystegia eurycoma* seed flour and starch extract were monitored for their color using color flex spectrocolorimeter (Model no. 45/0, CX1075, Hunter Lab Reston, VA, USA, 2002) after being standardized using Hunter lab color standards. The parameters recorded were L, a and b co-ordinates of the CIE scale. The pH of *Brachystegia eurycoma* flour and starch was measured immediately on the homogenate at 28°C by potentiometeric technique according to method of the Official Methods of AOAC (1990).

Chemical analysis: Protein, fat, ash, crude fibre, amylose and moisture contents were determined for the *Brachystegia eurycoma* flour and starch extract. These analyses were made according to the AOAC (1990) official procedures. The nitrogen was determined with a Kjeldahl method. The protein was calculated by Nitrogen ×6.25. Fat was obtained from a 4 h extraction with hexane. Ash was calculated from the weight remaining after heating the sample at 550°C for 2 h. Moisture was from the weight loss after oven drying at 110°C for 2 h. The starch content of the flour and starch extract was determined by the polarimetric method of AOAC (1990).

Swelling power and solubility pattern: About 1.0 g of samples accurately weighed and quantitatively transferred into a clear dried test tube and re-weighed (w_1). The flour/starch was then dispersed in 50 cm^3 of distilled water using a mixer. The resultant slurry was heated at the desired temperature (65, 75, 85 and 95°C) for 30 min in a water bath. The mixture was cooled to 28±2°C and centrifuged at 2200 rpm for 15 min to separate the gel and supernatant. Then, the aqueous supernatant was removed and poured into dish for subsequent analysis of solubility pattern. After this, the weight of the swollen sediment was determined (w_2). Supernatant liquid (5 mL) was poured into a tarred evaporating dish and dried to a constant weighed in air oven at 100°C for 4 h. Water solubility index was determined from the amount of dried solids obtained after drying the supernatant and was expressed as gram dried solids per gram of sample.

$$\text{Swelling power of sample (\%)} = \frac{w_2 - w_1}{\text{Weight of sample}}$$

Water and oil absorption capacity: The centrifugal method was used to determine the water and oil absorption capacities of the flour and starch isolate from *Brachystegia eurycoma* seeds. About 1 g of sample was mixed with 10 mL of distilled water/oil with variwhirl mixer for 30 sec. The samples were then allowed to stand at 30, 60, 70, 80 and 90°C, respectively for 30 min, before centrifuged at 5000 rpm for 30 min and the volume of the supernatant noted in a 10 mL graduated cylinder. Density of distilled water was assumed to be 1 g mL^{-1} and that of oil (grand pure soya cooking oil, Nigeria) was found to be 0.89 g mL^{-1}. Results were expressed on a dry weight basis.

Pasting properties determination: Pasting characteristics were determined with a Rapid Visco Analyzer (RVA) (Model RVA 3D+, Newport Scientific Australia). First, 2.5 g of *Brachystegia eurycoma* flour and starch isolate sample were weighed into a dried empty canister; then 25 mL of distilled water was dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister was well fitted into the RVA as recommended. The slurry was heated from 50-95°C with a holding time of 2 min followed by cooling to 50°C with 2 min holding time. The rate of heating and cooling were at a constant rate of 11.25°C per min. Peak viscosity, trough, breakdown, final viscosity, set back, peak time and pasting temperature were read from the pasting profile with the aid of thermocline for windows software connected to a computer (Newport Scientific, 1998). The viscosity was expressed in terms of Rapid Viso Units (RVU), which is equivalent to 10 centipoises.

Statistical analysis: Analysis were done in triplicate. Analysis of variance was performed to calculate significant differences in treatment means and LSD ($p<0.05$) was used separation means using SPSS/12 soft ware for windows.

RESULTS AND DISCUSSION

Physico-chemical properties of *Brachystegia eurycoma* flour and starch: The colour of starch due to the presence of polyphenolic compounds, ascorbic acid and carotene has impact on its quality. Any pigmentation in the starch is carried over to the final product. This reduces the quality, hence acceptability of starch product (Galvez and Resurreccion, 1993). A low value for chroma and a high value for lightness are desired for the starch to meet the consumer preference. In terms of starch colour (Table 1), it was observed that achi starch had a high value of whiteness (L = 81.33) and a low value of chroma (a = 2.36). Thus, in this study colour of *Brachystegia eurycoma* starch isolate can meet consumer preference due to the highest whiteness and low chroma values. pH value is one of the physico-chemical properties of starch important to application. Starch isolated from achi (5.78) has approximately the same pH value (Table 1) compared to other various native starches (Swinkels and Veedam, 1985). Similar observation has been reported for improved haricot bean by Shimelis *et al.* (2006).

The chemical composition of flours and starches from *Brachystegia eurycoma* seeds determines their pasting and other characteristics. Table 2 shows the chemical composition of *Brachystegia eurycoma* flour and starch extract. The starch yields obtained in this study was

Table 1: Colour analysis and pH value of 'achi' flour and starch extract

	Colour			
Parameters	L	a	b	pH
Flour	66.44	2.74	13.48	5.38
Starch extract	81.33	2.36	14.08	5.78

Values are means of triplicates. L = lightness (black/white), a = chroma (green/red) and b = hue (blue/yellow)

Table 2: Chemical composition of achi flour and starch extract

Samples	Moisture content	Crude protein	Crude fat	Total ash	Crude fibre	Starch yield	Starch
	(%)						
Flour	10.25	12.77	10.52	1.48	2.22	-	58.77
Starch extract	8.98	0.61	0.25	0.79	0.69	48.20	85.32

All values are means of triplicates

47.28 g/100 g. The starch yield obtained in this study was in agreement with data reported for many legume starches. Naivikul and D'Appolonia (1979) reported yields of 40.3, 38.3, 42.5 and 34.5% for navy bean, pinto bean, faba bean, lentil and mung bean starches, respectively. Starch yields of 49.3 and 59.3% for pigeon pea and mung bean starches, respectively had been reported by Singh *et al.* (1989). Similarly, Barimalaa *et al.* (2005) reported starch yields of 47.9, 45.52 and 42.75 g/100 g seed from four different varieties of bambara groundnut. Banigo and Mepba (2008) reported starch yields of 45.9-47.1 and 54.6% for African yam bean and cowpea starches, respectively. The values of the chemical composition of the flour were protein content 12.77%, crude fat 10.52, starch 58.77%, ash 1.48% and fibre content 2.22%. These results are comparable with that reported for *Brachystegia eurycoma* flour and other legumes seeds (Giami and Wachuku, 1997; Enwere, 1998; Onweluzo, 1991; Uhegbu *et al.*, 2009). The achi flour contained lower protein and higher fat content than that of mung bean flour (Amarteifio and Moholo, 1998), bambarra groundnut (Sirivongpaisal, 2008).

The chemical composition is a simple and convenient way illustrating the purity of the starch extracts, whereby higher starch and lower contents of other components (protein, fat, ash, fibre) are highly desirable. The protein, fat, ash and fibre contents of *Brachystegia eurycoma* starch were lower than the flour, but higher than that of bambarra groundnut (Sirivongpaisal, 2008; Lawal *et al.*, 2004), jack bean starch (Lawal and Adebowale, 2005). The results indicate that pure starch could be obtained from *Brachystegia eurycoma*. The result also implied that *Brachystegia eurycoma* starch is less pure compared to the normal corn, bambarra groundnut and jack bean starches. Schoch and Maywald (1968) reported that high contents of other components, especially fat and protein, influence the swelling power and pasting properties of starches. Report of many other investigators also indicated that the amount of protein, fat, ash and fibre are usually considered as an index of purity of legume starch

Table 3: Amylose and amylopectin content of achi flour and starch extract

Samples	Amylose (%)	Amylopectin (%)	Amylose/ Amylopectin ratio
Flour	18.73	81.27	0.230
Starch	20.88	79.12	0.264

All values are means of triplicates

(Lii and Chang, 1981; Galvez and Resurreccion, 1993). The starch content of *Brachystegia eurycoma* flour used in this study was 58.77% in dry matter. This result was comparable with reported values that starch content ranges from 35-60% of the dry weight of beans (Rockland and Metzler, 1967; Reddy *et al*., 1984). A similar finding was also reported by Labaneiah and Luh (1981) for starch content of red kidney beans, gloria pink dry beans and black eye beans, 46.95, 42.31 and 41.18%, respectively. Also, Shimelis *et al*. (2006) reported that the starch content for improved haricot bean flour ranged between 46.53 and 48.77% in dry matter.

The apparent amylose contents of the starch extract and flour obtained in this study were 20.88 and 18.73%, respectively in dry matter (Table 3). Thus, the results were similar to those reported for black bean, improved haricot bean and other legumes starches (Lai and Varriano-Marston, 1979; Labaneiah and Luh, 1981; Kim *et al*., 1996; Galvez and Resurreccion, 1993), but lower than that of mung bean starch (Su *et al*., 1997). The amylose portion of the starch affects its swelling and hot-paste viscosities (Shimelis *et al*., 2006). Schoch and Maywald (1968) stated that as the amylose content increases, the swelling tends to be restricted and the hot paste viscosity stabilized. Moreover, higher amylose contents are desired in starches that are to be used for the manufacture of noodles (Lii and Chang, 1981). The amylose content of starch samples along with the other components present has a good bearing on the pasting properties.

Functional properties

Swelling power and water solubility index: Swelling power and solubility of flour and starch from *Brachystegia eurycoma* were temperature dependent as indicated in Fig. 1 and 2. Both swelling power and solubility increased with increase in temperature. Swelling power is an indication of the water absorption index of the granules during heating (Loos *et al*., 1981). Moorthy and Ramanujam (1986) suggested that the swelling power of granules reflected the extent of the associative forces within the granule. From Fig. 2, it was observed that the solubility pattern had a correlation with the swelling power. With increase in swelling power, starch solubility also increased. Dengate (1984) stated that this is seen as mainly the result of granule swelling permitting the exudation of amylose. Low solubility of legume starches

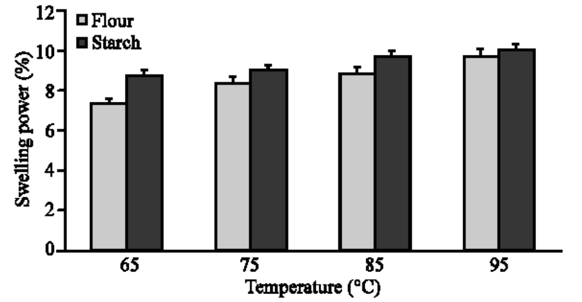

Fig. 1: Effect of temperature on swelling power of *Brachystegia eurycoma* flour and starch extract. Error bars: SD. Results are means of triplicate determinations

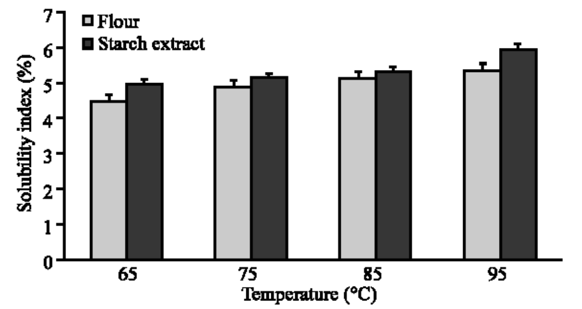

Fig. 2: Effect of temperature on solubility index of *Brachystegia eurycoma* flour and starch extract. Error bars: SD. Results are means of triplicate determinations

with increases at elevated temperatures had been reported (Leach *et al*., 1959; Swinkles, 1985; Henshaw and Adebowale, 2004; Lawal *et al*., 2004; Yusuf *et al*., 2007; Banigo and Mepba, 2008). In all these investigations, highest solubility and swelling power of starches were in the temperature range of 80-95°C and suggest that water penetration into the granules can be achieved at elevated temperatures. Thus modification of legume starches could be important to absorption and retention of water to increase swelling powers of starches required in the manufacture of confectionery goods. The swelling power and water solubility index of *Brachystegia eurycoma* starch and flour at 95°C were (10.05%) and (5.95%), respectively for starch, while the swelling power and solubility index of *Brachystegia eurycoma* flour were (9.64%) and (5.34%), respectively. The solubility of *Brachystegia eurycoma* starch in this study was lower to the observations reported by Lai and Varriano-Marston (1979) for black bean starch (17.91%) solubility at 95°C). Lii and Chang (1981) also reported that solubility and swelling power for red bean starch was about 25 and 32%, respectively. From the obtained results, *Brachystegia* *eurycoma* flour and isolated starch exhibited highly restricted swelling power and solubility. Compared with *Brachystegia eurycoma* starch, the swelling power and solubility patterns of flour indicated the existence of strong bonding forces. This may be due to its high amount of protein and fat (Table 2) that might form inclusion complexes with amylose. The lower value of solubility and swelling power of *Brachystegia eurycoma* flour to starch isolate might be due to the protein-amylose complex formation in *Brachystegia eurycoma* flour and isolated starch. According to Pomeranz (1991), formation of protein-amylose complex in native starches and flours may be the cause of decrease in swelling power.

Shimelis *et al.* (2006) reported that starch and protein interact due to attraction of their opposite charges and form inclusion complexes during gelatinization and this restricts swelling. Leach *et al.* (1959) and Zeleznak and Hoseney (1987) reported that the amylose acts both as diluents and inhibitor of swelling, especially in the presence of lipids which can form insoluble complexes with some of the amylose during swelling and gelatinization. The starch molecules are held together by hydrogen bonding in the form of crystalline bundles, called micelles. Thus, swelling power and solubility patterns of starches have been used to provide evidence for associative binding force within the granules (Leach *et al.*, 1959). When an aqueous suspension of starch granules is heated, these structures are hydrated and swelling takes place. According to Schoch and Maywald (1968), starches have been classified as high swelling, moderate swelling, restricted swelling, or highly restricted swelling. High-swelling starches have swelling power of approximately 30% or higher at 95°C. Their granules swell enormously and the internal bonds become fragile toward shear when the starch is cooked in water.

Restricted-swelling starches have swelling power in the range of 16-20% at 95°C. The cross-linkages in their granules reduce swelling and stabilize them against shearing during cooking in water (Galvez and Resurreccion, 1993). In this study, *Brachystegia eurycoma* starch and flour had swelling power of 10.05 and 9.64%, respectively. Therefore, the resulting swelling power indicated that the starch extract obtained was highly restricted type according to Schoch and Maywald (1968).

Water and oil absorption capacity: Imbibition of water is an important functional trait in foods such as sausages, custards and doughs. Moreover, oil absorption capacity is useful in structure interaction in food especially in flavour retention, improvement of palatability and extention of shelf life particularly in bakery or meat products (Adebowal and Lawal, 2004). The water and oil absorption capacities of *Brachystegia eurycoma* flour and starch were temperature dependent as indicated in Fig. 3 and 4. Results of water absorption capacity in this study was 85.33% for starch and 81.18% for flour at 30°C (Fig. 3) and which were less compared to previous observations by Sosulski and Fleming (1977), who reported that the water absorption by soybean flour, soybean concentrate, sunflower flour and sunflower concentrate were 24, 360, 180 and 390%, respectively. Sathe and Salunkhe (1981a) reported 2.93 g g^{-1} water absorption capacity for Great Northern bean starch. The high water absorption observed may have been due to the nature of the starch and possible contribution to water absorption by the cell wall material (s), which was not removed completely (Sathe and Salunkhe, 1981b). The water and oil absorption profile increased with temperature. In general, water and oil absorption capacity

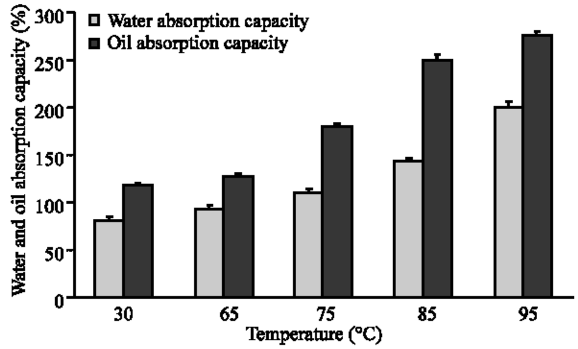

Fig. 3: Effect of temperature on oil and water absorption capacities of *Brachystegia eurycoma* flour. Error bars: SD. Results are means of triplicate determinations

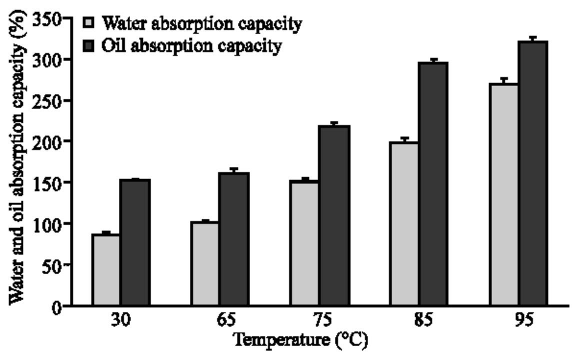

Fig. 4: Effect of temperature on oil and water absorption capacities of *Brachystegia eurycoma* starch extract. Error bars: standard deviations. Results are means of triplicate determinations

values of *Brachystegia eurycoma* starch were higher than that of the flour at all temperatures studied. This different behaviour could be attributed to the difference in amylose/amylopectin ratio, as well as to the difference in chain length distribution as reported for other starches (Bell-Perez *et al*., 2002). Studies on purification modification and properties of pea starch reported by Comer and Fry (1978) have concluded that cold water absorption of purified pea starch was 92-105% and that water uptake was a function of temperature. Chou and Morr (1979) reported that water binding by starches is a function of several parameters including size, shape, conformational characteristics, steric factors, lipids and carbohydrates associated with the proteins and others. The result also showed that *Brachystegia eurycoma* starch had a higher oil absorption capacity (321%) than the flour (275%) (Fig. 4). Hutton and Campbell (1981) reported that the ability of food to absorb water and oil may help to enhance sensory properties such as flavour retention and mouth feel. This statement therefore implies that *Brachystegia eurycoma* starch will have a higher degree of flavour retention and month feel than the flour and will be improved better at an elevated temperature.

Pasting behaviour: Results of the pasting properties of normal corn starch, *Brachystegia eurycoma* flour and starch extract are shown in Table 4. There were significant differences ($p<0.05$) in the pasting profile of the normal corn starch, *Brachystegia eurycoma* flour and starch extract. Several changes may occur upon heating a starch-water system, including enormous swelling, increased viscosity, translucency and solubility and loss of anisotropy (birefringence). These changes are defined as gelatinization. The RVA results indicated that starch isolates and flour from *Brachystegia eurycoma* seeds had distinct pasting properties compared to normal corn starch. The pasting temperature of the normal corn starch, *Brachystegia eurycoma* flour and starch were 84.80, 88.25 and 84.10°C, respectively. The gelatinization temperature obtained was considerably higher than that for wheat starch 55.6-63.0°C, chick pea 63.5-69.0°C and horse bean 61.0-70°C starches but within the range for improved haricot bean starch 84.4-86.4°C (Lineback and Ke, 1975; Shimelis *et al*., 2006). Many investigators have reported that different bean types contain different ranges of pasting temperature, for example purified haricot bean starch ranged between 65.5-68.5°C (Naivikul, 1977); great Northern bean between 65.5-68.5°C (Sathe and Salunkhe, 1981a). Similarly, lower gelatinization temperature compared to the observed results was also reported for kidney bean; Yang *et al*. (1991); black bean Lai and Varriano-Marston (1979).

Table 4: Pasting characteristics of achi flour and starch extract

Samples	Viscosity (RVU) $P_{temp.}$ (°C)	P_{Time} (min)	PV	TV	FV	BD	SB
Flour	88.25	7.00	77.58	23.83	429.50	53.80	405.70
Starch	84.10^{b}	5.20^{b}	275.42^{b}	229.25^{b}	462.83^{b}	46.17^{b}	233.58^{b}
Corn starch	84.80^{b}	5.33^{b}	267.08^{b}	225.50^{b}	441.17^{c}	41.58^{c}	215.67^{c}

Values are means of triplicate determinations. Means in the same columns with different superscripts differ significantly ($p<0.05$). $P_{Temp.}$ = Pasting temperature; P_{Time} = Pasting time (min); PV = Peak Viscosity; TV = Trough Viscosity; FV = Final Viscosity; BD = Break Down; SB = Set Back

The high initial gelatinization temperature of *Brachystegia eurycoma* starch indicated that the granules resisted swelling (Fig. 1). Generally, starch isolates exhibited a lower viscosity during heating to 95°C, at 95 and 50°C compared to *Brachystegia eurycoma* flour. The pasting temperature is one of the pasting properties which provide an indication of the minimum temperature required for sample cooking, energy costs involved and other components stability (Shimelis *et al*., 2006). The peak viscosity which is the ability of starch to swell freely before their physical breakdown ranged between 77.58 and 275.42 RVU. Peak viscosities were 77.58 and 267.08 RVU for *Brachystegia eurycoma* flour and the starch, respectively. The peak viscosity indicates the water binding capacity of starch. The relatively high peak viscosity exhibited by *Brachystegia eurycoma* starch is indicative that the starch may be suitable for products requiring high gel strength and elasticity. The trough, which is the minimum viscosity value in the constant temperature phase of the RVA profile and measures the ability of paste to withstand breakdown during cooling ranged between 23.83 and 229.25 RVU. The trough values were 23.83 and 229.25 RVU for *Brachystegia eurycoma* flour and *Brachystegia eurycoma* starche, respectively. The normal corn starch had the lowest (41.58 RVU) breakdown viscosity, hence the higher the breakdown in viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking (Adebowale *et al*., 2005). Hence, normal corn and *Brachystegia eurycoma* starches might be able to withstand heating and shear stress. The final viscosity, which is the change in the viscosity after holding cooked starch at 50°C ranged between 429.5 and 462.83 RVU. The final viscosity values were 429.5, 441.17 and 462.83 RVU for *Brachystegia eurycoma* flour, normal corn and *Brachystegia eurycoma* starches, respectively. *Brachystegia eurycoma* starch had higher final viscosity (462.83 RVU) compared to the *Brachystegia eurycoma* flour and normal corn starch. Final viscosity is used to define the particular quality of starch and indicate the stability of the cooked paste in actual use; it also indicates the ability to form various paste or gel after cooling and less stability of starch paste commonly accompanied with high value of breakdown. The setback value of the *Brachystegia eurycoma* flour, starch and normal corn starch were 405.7, 233.58 and 215.67 RVU, respectively. The higher the setback value, the lower the retrogradation during cooling of the products made from the flour.

Classification of viscosity pattern is important to categorize the starch for end product recommendation. According to Schoch and Maywald (1968) viscosity pattern taxonomy of thick-boiling starches, the swelling power of 16.82% obtained in this experiment for *Brachystegia eurycoma* starch isolate classifies it as restricted-swelling starch. A restricted type of swelling is mostly desired for the starch extracts for the manufacture of value added products such as noodles. Composite blends with cereals importantly require that the starch granules swell sufficiently and remain intact and stable against sheering during the process (Galvez and Resurreccion, 1993). Sathe *et al.* (1982) observed that black gram starch amylograph had a strikingly different behaviour than most legume starches in that it had a distinct peak viscosity. It was observed that pasting properties of *Brachystegia eurycoma* starch had higher value of peak and final viscosity pattern than *Brachystegia eurycoma* flour, which is a common behaviour of most legumes.

Legume starches have higher viscosity than cereal starches (Lineback and Ke, 1975), which indicate that these starches are more resistant to swelling and rupture towards shear. From Table 4, it was observed that viscosity result is in agreement with the findings of Lineback and Ke (1975). The factors which influence this property may include the size and shape of the starch granules, ionic charge on the starch, kind and degree of crystallinity within the granules, presence or absence of fat and protein and perhaps, molecular size and degree of branching of the starch fractions (Schoch and Maywald, 1968). The pasting profile results in this study were not in agreement with the findings of Liang and King (2003), where flour had higher paste viscosity than starch.

CONCLUSION

The *Brachystegia eurycoma* flour contains high quantities of carbohydrate, protein and fat. The *Brachystegia eurycoma* starch has high amylose content and the swelling power of flour and starch isolate fall on the group of restricted-swelling starches. The characteristic is desirable for starch extracts to be used for the manufacture of value-added products and composite blends with cereals. The decrease in paste viscosities of *Brachystegia eurycoma* flour compared to starch obtained in this study are attributed to the interaction of starch with the protein, fat etc., which plays an important role in governing the pasting properties of starch. The results of the physico-chemical, pasting and functional properties obtained indicate that *Brachystegia eurycoma* starch have useful technological properties for many applications. It can be used in the food processing industry and non-food applications of starch such as in paper and textile industries. The functionality and pasting data show that *Brachystegia eurycoma* starch can be used as a functional ingredient in food systems, particularly in the South-East of Nigeria and Nigeria in general, where *Brachystegia eurycoma* is produced and utilized.

Finally, in order to boost the small scale *Brachystegia eurycoma* production and develop new market opportunities to stimulate economic growth in the South-East of Nigeria, one would have to expand alternative utilization/processing techniques in Agro-food systems.

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